Mass Loss and Gas Release During Torrefaction of Biomass and its Constituents

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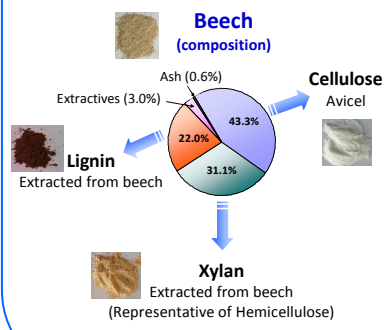
Objective

Modeling of biomass torrefaction **(200-300°C, N_2)** → **Is the additive law valid?**

$$\Delta m_{biomass} \overset{?}{=} \Delta m_{cellulose} \cdot \%_{cellulose} + \Delta m_{lignin} \cdot \%_{lignin} + \Delta m_{hemicellulose} \cdot \%_{hemicellulose}$$

Experiments: Torrefaction of beech wood, and its constituents (Cellulose, Hemicellulose and Lignin)

Samples



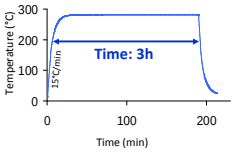
Before torrefaction: samples dried at 105°C during 24h

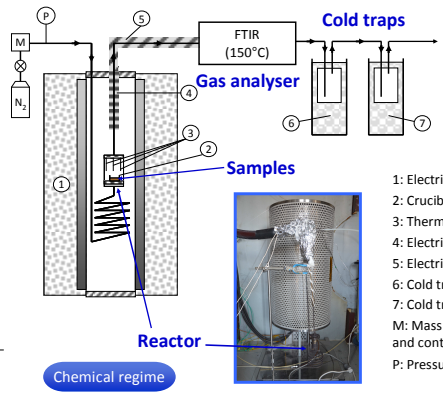
Mass balance and volatiles release: TORNADE

Operating conditions

T = 220°C, 250°C, 280°C, 300°C

Sample mass: 100-200mg
Gas carrier: N_2 (1NL/min)
P: 1bar





1: Electrical furnace
2: Crucible (Al)
3: Thermocouples
4: Electrical heater (220°C)
5: Electrical heater (180°C)
6: Cold trap (0°C)
7: Cold trap (-70°C)
M: Mass flow meter and controller
P: Pressure gauge

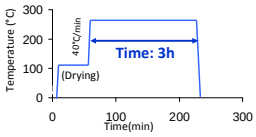
Mass loss kinetics: TGA

Operating conditions

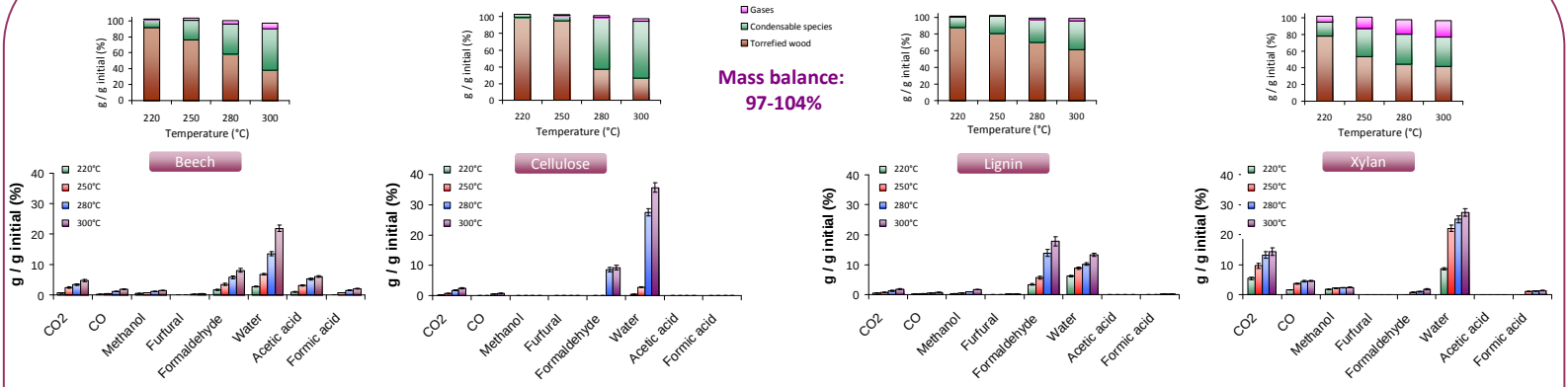
T = 220°C, 250°C, 280°C, 300°C

Sample mass: 5mg
Gas carrier: N_2 (0.03NL/min)
P: 1bar

Chemical regime

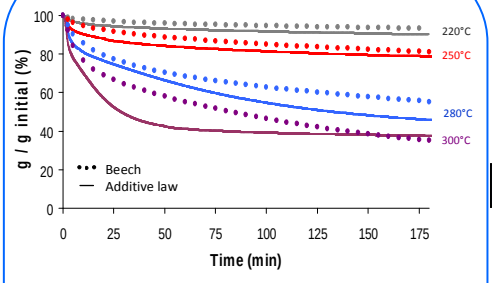


Mass balance and volatiles release



- Main volatile species released:
  Steam, Formaldehyde, Acetic Acid, CO_2
  Methanol, CO, Formic Acid, Furfural
- Drastic change between 250°C and 280°C in cellulose torrefaction
- CO_2 and CO mainly released by Xylan torrefaction
- Acetic Acid not produced by Cellulose/Hemicellulose/Xylan
  - produced from acetyl groups (Hemicellulose) removed during extraction
- Formic Acid only produced by Xylan decomposition

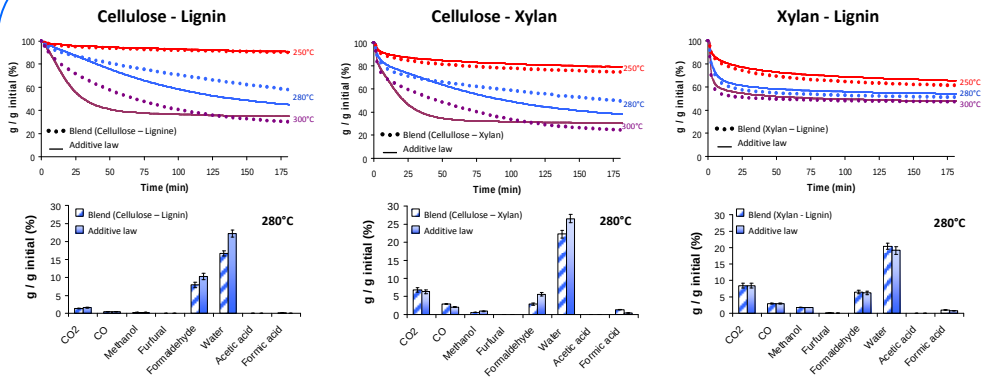
Modeling approach: additive law



- **Valid at low temperature (T ≤ 250°C)**
- **Not Valid at high temperature (T ≥ 280°C)**

→ **Interaction** between beech constituents?

Mix of wood constituents



→ Significant **interactions** between **Cellulose** and **Lignin/Xylan** from **280°C**

→ **No** significant **interaction** between **Xylan and Lignin**

Conclusion

- **Additive law valid at T ≤ 250°C and not at T ≥ 280°C**
  - **Interactions between Cellulose and Lignin/Xylan**
  - **No interactions between Lignin and Xylan**
- **Main volatiles species to be modeled are produced from different constituents (except Formic Acid)**

Further work

- To develop a kinetic model predicting:
  - the mass loss
  - the gas composition
- Interactions origin?